

ACOUSTICAL STUDIES OF SEDIMENT DYNAMICS IN THE SURF ZONE: SANDYDUCK'97

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LONG-TERM GOALS

The central goal of this project is a deeper understanding of the dynamic adjustment of mobile sandy sediments to fluid forcing in the surf zone at small (1cm to 10m) and intermediate (10m to 100m) horizontal scales. The effort is motivated by the dual need to develop more realistic models of fluid-sediment interactions in the nearshore zone, and for suitable in situ measurement techniques to make the observations necessary to adequately test the models. Of particular interest is the role of bedforms of different characteristic spatial pattern and scale in the local sediment flux and momentum balances.

OBJECTIVES

The overall objective of this project is to study bedform genesis, growth, migration, and decay, together with the associated fluid forcing and sediment suspension, in the natural surf zone. A key initial objective is to obtain a comprehensive set of measurements of bed adjustment through time, as a function of cross-shore position, and over a period of several months. This data set will provide a basis for determining cross-shore differences in response synoptically, and for differences in the response trajectories through time and between forcing events, over a suitably wide range of conditions.

APPROACH

The approach is based upon an array of state-of-the-art underwater acoustic sensors for high-resolution measurements of seabed topography, and fluid velocity and sediment concentration profiles through the wave-current boundary layer. The array comprises 5 instrumented frames deployed along a cross-shore line and along an alongshore line with 50-100 spacing between adjacent frames. Rotary fan and pencil-beam imaging sonars are mounted on each frame. Coherent Doppler profiling systems, augmented by Sontek ADV-O point velocimeters, are mounted on two of the frames. Pressure and temperature sensors, and electromagnetic flowmeters, and 2-axis tilt sensors are deployed on each frame.

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The coherent Doppler system was developed with Dr. Len Zedel (Memorial University), with funds from ONR. Dr. Zedel and I continue to collaborate on this development. The rotary sonar system operates in master/slave mode, so that data from a number (up to 8) different heads may be acquired simultaneously. This is accomplished with custom electronics developed at Dalhousie during the past year. Technical support for the Doppler and rotary systems is provided by Wes Paul (electronics and acoustics technologist) and Dr. Robert Craig (data acquisition and control software). The em flowmeters and pressure/temperature measurements are made by colleague Dr. Tony Bowen (Dalhousie University), as part of a separately-funded collaborative research project. David Hazen (electronics engineer) is the key technical support person for this equipment and the associated data acquisition system. Walter Judge (electronics technologist) provides additional technical support. Both Hazen and Judge are qualified SCUBA divers, and provide essential diving support during field experiments.

WORK COMPLETED

As this report is being written, data from the acoustic remote sensing array are still streaming into the data acquisition trailer, 10 weeks after being deployed as part of the SANDYDUCK'97 Nearshore Dynamics Experiment at the US Army Corps of Engineers Field Research Facility in Duck, North Carolina. We have acquired a total of 200 GBytes of data, including 50,000 images of the seabed. Four instrument frames were deployed in the first week of August, the fifth in the first week of September, as scheduled in the SANDYDUCK'97 logistics plan. A sixth frame was also successfully deployed, but it has not yet been possible to instrument it because of the anomalous behaviour of the nearshore bar/trough system at Duck this year. The instruments have been operating continuously since deployment, producing data at a rate of about 2 Gigabytes/day. The sole failure has been a faulty splice in an interconnect cable to one instrument on one frame. This interconnect cable was replaced in the last week of August, and there have been no instrument problems since.

A major task prior to SANDYDUCK'97 was the development and testing of the hardware and software needed for the data acquisition and control system which operates the array. The system involves four data acquisition nodes, two on land and two offshore, and a central control and storage node. The system is semi-autonomous: operator intervention is required to change data storage media, and for alterations to the system configuration and operating parameters to accomodate major changes in local water depth. The system has been operating flawlessly for the past two months.

A significant effort is being made to process this large-volume data set in the field. The data are undergoing the first stages of processing at the experiment site, including a battery of data quality checks, and summary raw data products to guide subsequent analyses. Todd Mudge (computer programmer) has been developing methods for routine processing and presentation of the acoustic data, including computer animations. To this point, roughly two thirds of the acoustic imagery have been processed.

RESULTS

We have obtained, for the first time, synoptic measurements of bedform evolution at cm-to-10m scales across the surf zone over a several month period. The quality of the data are uniformly high, with one exception: periods when the sensors are either buried or too close to the bed to produce useful data. Sensor burial has occurred only at our 2 innermost frames, and has been partially mitigated by raising the frames between storms. The positive view of this one problem is that the data leading up to burial are highly likely to provide useful insights into sediment deposition processes on nearshore bars.

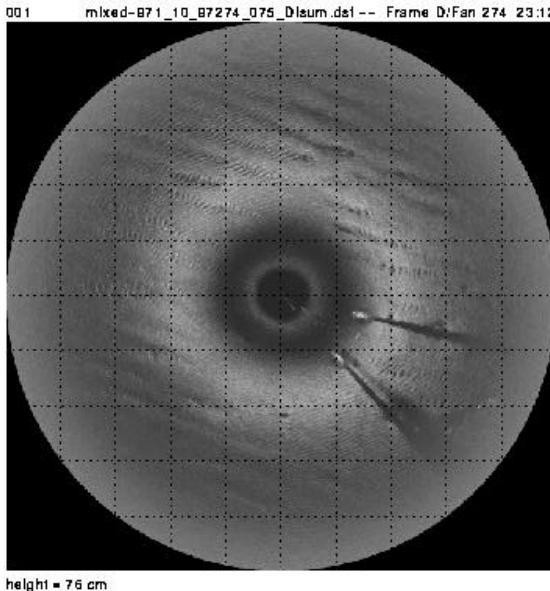


Figure 1: Fan Beam Image of Cross Ripples

bed behaviour: flat bed, alongshore and cross-shore migrating lunate megaripples, the growth and decay of lunate megaripples, and rich complexity of cross-ripple types, irregular ripple fields, long-crested anorbital ripples, and long-crested orbital ripples. The cross-shore distribution of these different bed states is sometimes consistent with Clifton's (1976) cross-shore progression, and sometimes not.

An example of a cross-rippled bed, showing obliquely-intersecting ripples with 2 distinct spatial scales, is shown in the accompanying Figure 1. The image is 10 m in diameter and the grid separation is 1m.

Figure 2 shows cross-shore bed elevation profiles as a function of time. The profiles were acquired at 10 minute intervals and are offset in the vertical. The onshore migration of the larger scale ripples is quite distinct.

We have obtained, for the first time, simultaneous, collocated vertical profiles of velocity and suspended sediment concentration data from a coherent Doppler profiling system deployed continuously within the surf zone, for a wide range of bedform types and forcing conditions.

The data set comprises a rich range of

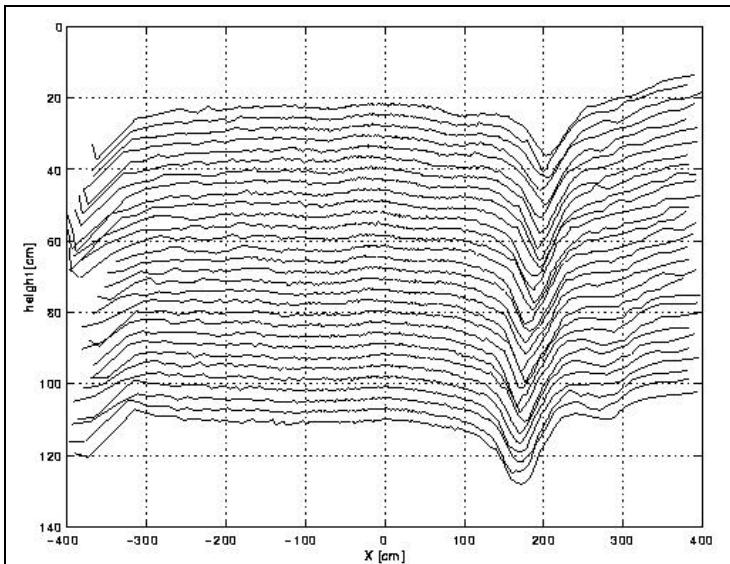


Figure 2: Bed Profiles of Migrating Megaripple

Unlike DUCK'94, flat bed occurred frequently at our instrument locations during SANDYDUCK'97. This is quite a useful result, because it means that the occurrence parameters for the different bedform types can be directly compared to those for this high-energy bed state, within the same data set.

IMPACT

In the SANDYDUCK'97 experiment, we have demonstrated that it is possible to make long-term observations of nearshore fluid-sediment interactions with sophisticated measurement systems on a continuous basis at a number of cross-shore locations. The data set is of high quality and, because of the combination of Doppler profilers, the 3-dimensional seabed imaging systems, and the 3-month's duration, it is also unusually comprehensive. During the next several years, it can be anticipated that, through comparisons of these results with model predictions (i.e. Wilson and Hay, 1997; Hay and Bowen, 1997), significant new insights into mobile bed dynamics in the surf zone will result. In addition, the successful performance of the acoustic remote sensing array throughout SANDYDUCK for a wide range of surf zone conditions opens up a variety of new possibilities for these kinds of instruments in future nearshore dynamics experiments.

TRANSITIONS

Numbers of groups world-wide are making use of our advances in the use of acoustics for the sediment transport studies, including our recent introduction of rotary imaging sonars for bedform measurements (see Hay and Wilson, 1994).

RELATED PROJECTS

A significant benefit to this project was provided by a grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada to Dr. Alex Hay (Principal Investigator), and Co-Investigators: Dr. Tony Bowen (Dalhousie University), Dr. J. C. Doering (University of Manitoba) and Dr. Len Zedel (Memorial University of Newfoundland) to allow this team to participate in the SANDYDUCK'97 experiment. The NSERC grant covered most of our field costs.

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